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Multiphase Flow Calculations in CartaBlanca

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What is CartaBlanca

CartaBlanca is a multi-material and multi-physics code.

- Based on the advanced multi-material interaction theory.
- Uses unstructured mesh (for complex geometries).
- Written in Java, taking advantage of object-oriented Java structure.
- Easy to add user modules. ([Developer friendly](#)).

Traditional fluid dynamics:

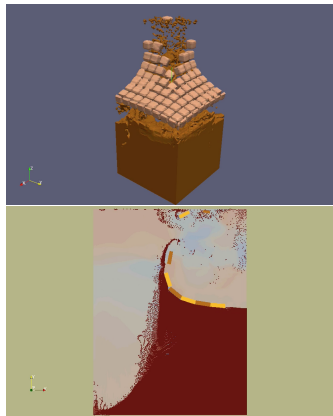
- Reacting multiphase flows. Fluidized bed.
- Heat and mass transfer for nuclear reactors.
- Nuclear fuel separation in centrifugal contactors.
- Multiphase flows and reactions in porous material.

Advanced multi-material interactions:

- Fluid-structure interactions.
- Hypervelocity impact in air or under water.
- Material pulverization and solidification.
- Structure dynamics (e.g. Blast loading).

A Brief History of CartaBlanca

- Started as a small project about 20 years ago with the goal to build a test bed for new material models and new numerical algorithms.
- R&D 100 award, 2005.
- Used in many projects by universities and companies:
 - △ Penn State, MIT, Columbia, U. Taxes, ...
 - △ BP, Chevron.
 - △ Acta Inc. (A DoD contractor)
 - ◇ Massively parallel implementation
 - ◇ K & C Concrete model
 - ◇ ParaView post processing



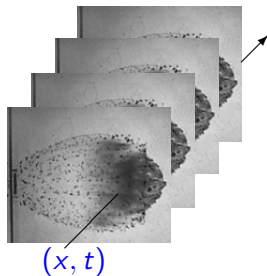
Courtesy of Acta Inc. Torrance, CA

Ensemble Phase Averaging Method

Multiphase flows are stochastic and multiscale. Common theories are based on volume averaging method.

- What is the size of the representative volume element (RVE)? Does such a size exist?

Ensemble Phase Average: Average over many experiments.



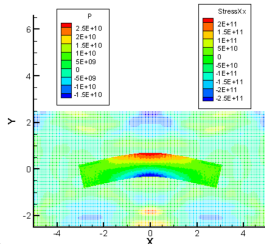
$$\text{Vol. frac.}(x, t) = \frac{\# \text{ of times } (x, t) \text{ in the phase}}{\# \text{ of exps.}}$$

$$\text{Avg. vel. of a phase } (x, t) = \frac{\text{sum of vel's when } (x, t) \text{ in the phase}}{\# \text{ of times } (x, t) \text{ in the phase}}$$

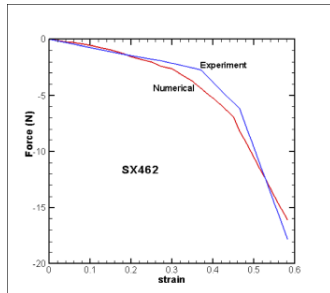
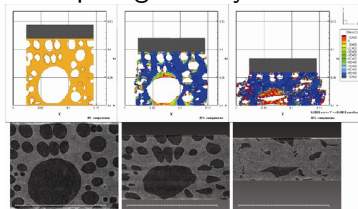
- No need for RVE.
- More directly related to physics at lower length and time scales. Less human interpretation of physics.

Multi-velocity Formulation

- Each material can have its own velocity, stress, and internal energy fields.
- Material interactions are considered through interaction forces in the equations not through the material interfaces.
- Applicable in cases of “body interactions”.

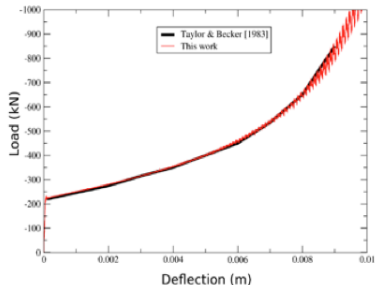
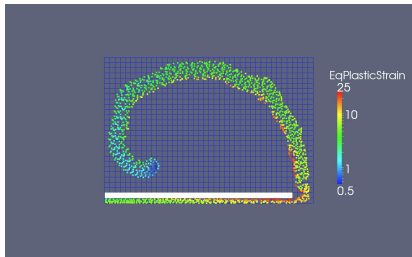


Dual domain material point method (DDMP) for complex geometry:

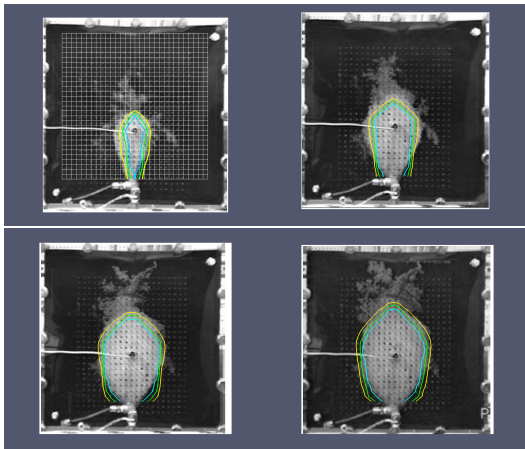


DDMP for Extreme Deformation

- Particle-in-cell (PIC) method invented by Frank Harlow in the 1960s.
- In the late 1980s, shape functions were introduced (FLIP).
- In the 1990s, reformulated using virtual work theory (MPM).
- Improved with noise reduction technique (DDMP) (2011).
- Applicable for history dependent problems with large deformation. It has very little numerical diffusion.



Steam assisted gravity drainage (SAGD)

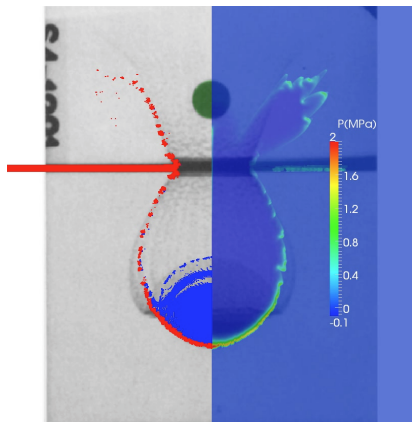
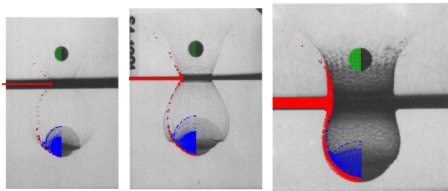


Formation of steam chamber

- Steam injection from the top well.
- Steam turns into water releasing latent heat on the wall of steam chamber.
- Oil temperature increases, and viscosity reduces.
- Oil drains to the bottom well under gravity.

Material Pulverization

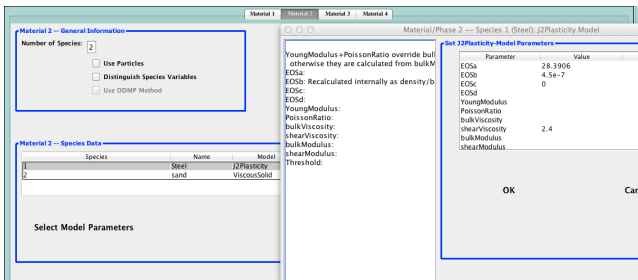
- An aluminum ball impacts on aluminum plates of various thicknesses.
 $V = 6.7 \text{ km/s}$.
- Red particles are calculated plate material.
- Blue particles are calculated ball material.



Input and Output

- Currently, upto 4 materials (4 separate velocity fields).
- Each material can contain many species.
- Each species can have an independent material model.
- Many material model selections from the pull-down menu.

- Easy to add new one.
(Developer friendly code.)



- >gov.lanl.cartablanca.physprop.materials
 - >AnisotropicElastic.java 1.10
 - >CubicElastic.java 1.2
 - >CubicKelvin.java 1.2
 - >EmulsionSagd.java 1.1
 - >EVP.java 1.3
 - >FoamyOil.java 1.3
 - >FortranModelOne.java 1.5
 - >GammaGas.java 1.5
 - >GenericSpecieResponse.java 1.18
 - >Granular.java 1.12
 - >Incompressible.java 1.7
 - >J2Plasticity.java 1.9
 - >JohnsonCook.java 1.20
 - >Kelvin.java 1.42
 - >Linear.java 1.10
 - >LinearSagd.java 1.2
 - >MaterialResponse.java 1.33
 - >Maxwell.java 1.2
 - >MieGruneisen.java 1.7
 - >NobleAbel.java 1.6
 - >PorousMediumSagd.java 1.1
 - >Rigidbody.java 1.5
 - >Sesame.java 1.5
 - >TEPLA.java 1.6
 - >ViscousSolid.java 1.12

We are interested in understanding new physics.

- Not a commercial code.
 - ◊ We will work closely with interested users.
 - ◊ Work with 1-3 users on a project.
- We focus on physical problems.
 - ◊ We will develop physical models together.
 - ◊ Our partners are **not** paying for code development.
 - ◊ They pay for capability development.
- We can design user interface together.
 - ◊ No one will need all of these capabilities.
 - ◊ Design a user interface for a category of problems.
 - ◊ Need user participation and feedback.